APPARATUS, AND ASSOCIATED METHOD, FOR FACILITATING SELECTION OF POWER LEVELS AT WHICH TO COMMUNICATE DATA IN A RADIO COMMUNICATION SYSTEM

The present invention relates generally to a manner by which to facilitate selection of a power level at which to send data in a radio communication system, such as a cellular communication system constructed pursuant to an IS-95 standard in which 1xEV-DO technology is deployed. More particularly, the present invention relates to apparatus, and an associated method, by which to select the power levels at which to send data upon a data channel, such as MAC data upon an MAC channel, to a mobile, or other communication, station. The mobile station generates a data rate request to request that the data be sent to the mobile station at a requested data rate. The requested data rate is used, in part, to select the power level at which the data is communicated. And, when the channel is used to communicate separate data to a plurality of separate mobile stations, the power levels at which the data is communicated is allocated in manners such that the total power level to communicate all of the separate data to all of the separate mobile stations is within a maximum allowable level. Power control is effectuated while utilizing an existing communication metric of data rate feedback requests.

BACKGROUND OF THE INVENTION

Advancements in communication technologies have permitted the introduction, and popularization of new types of communication systems. In various of such new types of communication systems, the rates of data transmission and the corresponding amount of data permitted to be communicated, has increased relative to existing types of communication systems.

New types of radio communication systems are exemplary of communication systems that have been made possible as a result of advancements in communication technologies.

Communication channels of a radio communication system are formed upon radio links, thereby obviating the need for conventional wire line connections between sending and receiving stations operable therein. A radio communication system, therefore, inherently permits increased communication mobility in contrast to conventional wire line systems.

A cellular communication system is exemplary of a radio communication system. Cellular communication systems, constructed according to various communication standards, have been installed throughout significant areas of the world. A mobile station operable in the cellular communication system permits a user to communicate telephonically therethrough when the mobile station is positioned within an area encompassed by the communication system.

The development and implementation of new cellular, as well as other, communication systems capable of communicating packet-formatted data have been made possible as a result of advancements in digital communication techniques. An exemplary cellular communication system which provides for the communication of packet-formatted data is set forth in the IS-95 standard promulgated by the EIA/TIA. Ongoing efforts are made to make improvements to the initial implementation of the standard. The IS-2000 standard, for instance, also sets forth operational parameters for a cellular communication system that is predicated, in part, upon the IS-95 system. Both the IS-95 and IS-2000 communication standards utilize CDMA (Code-Division, Multiple-Access) communication techniques. The standards are sometimes referred to as the IS-95/IS-2000 family of standards.

Deployment of a so-called 1xEV-DO technology together with an IS-95/IS-2000 based communication system has also been proposed. An IS-95 system which deploys 1xEV-DO technology is an evolutionary step from the IS-2000 system and deploys a packet data wireless technology. The 1xEV-DO technology is somewhat disjoined from the IS-95/IS-2000 family of

standards in that a system in which the 1xEV-DO technology is deployed is unable to share the same frequencies as the frequencies of existing IS-95 and IS-2000 systems. The 1xEV-DO technology utilizes TDMA (Time-Division, Multiple-Access) schemes instead of the CDMA access scheme utilized in the IS-95/IS-2000 standards.

In a system in which the 1xEV-DO technology is deployed, a channel is defined by a frequency and time slot combination. Pursuant to a communication session, system users are assigned time slots upon which to communication to effectuate the communications pursuant to the communication session. The time slots are sub-divided into three basic payloads. A data payload, an MAC (Medium Access Control) payload, and a pilot payload are all defined. And, the payloads each define a channel, i.e., a data channel, a MAC channel, and a pilot channel.

The MAC channel is utilized by all current users, i.e., mobile stations, at least within a selected area. Different users are assigned different Walsh spreading functions. The MAC channel is thereby a shared channel, and the power levels at which data is communicated upon the MAC channel must be controlled.

As presently promulgated, the IS-95 system which deploys 1xEV-DO technology fails to set forth a power control scheme by which to control the power levels at which data is communicated upon the MAC channel.

A manner by which to control the power levels of data communicated upon a MAC channel would facilitate the communication of the data in a manner to permit its detection at the mobile station to which the data is communicated.

It is in light of this background information related to packet radio communication systems that the significant improvements of the present invention have evolved.

SUMMARY OF THE INVENTION

The present invention, accordingly, advantageously provides apparatus, and an associated method, by which to facilitate selection of a power level at which to send the data in a radio communication system, such as a cellular communication system constructed pursuant to an IS-95/IS-2000 standard in which 1xEV-DO technology is deployed.

Through operation of an embodiment of the present invention, a manner is provided by which to select the power levels at which to send the data upon a data channel, such as MAC (Medium Access Control) data, upon a MAC channel sent upon a forward link to a mobile station.

A mobile station operable to receive the data monitors the received data to determine channel conditions of a radio link upon which the data is communicated. Responsive to measurements made during the monitoring, the mobile station generates a data rate request. The data rate request is a request for the data to be sent thereto at a particular data rate. The requested data rate is used as a metric by which to select the power level at which data is subsequently communicated to the mobile station.

When the channel is used to communicate separate data to a plurality of separate mobile stations, the power levels at which the data is communicated are allocated in manners such that the total power level of all the data communicated upon the data during a selected time interval is within an allowable power level. The total power level is the sum of the power levels of the separate data communicated to the separate mobile stations.

Operation of an embodiment of the present invention thereby advantageously provides a manner by which to effectuate power control over the data transmitted upon the data channel while using a communication metric of data rate feedback.

In one aspect of the present invention, the data channel forms a MAC (Medium Access Control) channel defined in an IS-95/IS-2000 system in which 1xEV-DO technology is deployed. The MAC channel is formed of a time slot defined in a TDM (Time Division Multiplex) access method. All current users in a portion of the communication system utilize the MAC channel. Each of the users, i.e., mobile stations, are allocated a Walsh function. Data to be communicated to separate ones of the mobile stations are encoded by the separate Walsh functions, thereby providing differentiation upon the MAC channel. Effectuation of power control is facilitated thereby to maintain the power levels at which the data communicated upon the MAC channel are collectively maintained within a maximum allowable level.

In another aspect of the present invention, a mobile station performs measurements to determine channel conditions upon a radio link extending thereto and upon which the MAC channel is defined. Responsive to the measurements, the mobile station determines the maximum data rate at which data subsequently to be sent to the mobile station should be communicated. Generally, when channel conditions are good, data is able to be communicated to the mobile station at relatively high data rates. Conversely, when the communication conditions are poor, the data rate at which data can be sent to the mobile station is relatively low. The mobile station generates a DRC (Data Rate Control) command, or other appropriate indications, of a requested data rate at which to communicate subsequent data to the mobile station.

In another aspect of the present invention, the DRC command, or other indication, is communicated to the network of the IS-95/IS-2000 system in which the 1xEV-DO technology is deployed. The network detects the DRC command, or other indication, and utilizes the value of

the command or indication as a metric by which to select the power levels at which to send subsequent data to the mobile station.

The total amount of power available to communicate separate data to separate mobile stations upon the MAC channel is defined. The total power level is, for instance, a system-defined parameter or, alternately, an operationally-selected parameter value. An average power level available by which to communicate data to N current users, i.e., mobile stations, is determined by dividing the total power level available by the number N of current users. And, the average power allocated to each data communication is further differentiated depending upon the value of the DRC command received at the network. The DRC command is of one of a finite set of values. The value of the DRC command is multiplied together with the average power available to each current user, and the product is multiplied by a gain factor. The gain factor is selected such that the summation of all the power levels at which the separate data are sent to the separate mobile stations upon the MAC channel are within a maximum allowable total power level.

In these and other aspects, therefore, apparatus, and an associated method, is provided for a two-way radio communication system. At least first selected forward-link data is communicated by a network station upon a forward link channel to at least a first selected mobile station. Selection of a power level at which the first selected forward-link data is communicated is facilitated. A first channel quality indicia measurer is positioned at the first selected mobile station. The first channel quality indicia measurer measures an indicia of communication quality levels upon the forward link channel and forms a first channel-quality indicia value responsive thereto. A first data rate selector is coupled to a first channel quality indicia measurer to receive the first channel-quality indicia value. The first data rate selector selects a first data rate at which

to communicate subsequent first selected forward-link data upon the forward link and forms a first data rate selection value responsive to selection made thereat. An indication of the first data rate selection value, when returned to the network station, is used to select the power level at which to communicate the subsequent first selected forward-link data to the first selected mobile station.

A more complete appreciation of the present invention and the scope thereof can be obtained from the accompanying drawings which are briefly summarized below, the detailed description of the presently preferred embodiments of the invention, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a functional block diagram of a packet radio communication system in which an embodiment of the present invention is operable.

Figure 2 illustrates a functional representation of operation of an embodiment of the present invention by which power levels are allocated for separate communications upon the shared MAC channel.

Figure 3 illustrates a method flow diagram listing the method of operation of an embodiment of the present invention.

DETAILED DESCRIPTION

Referring first to Figure 1, a functional representation of a communication system, shown generally at 10, operates to communicate data by way of radio channels defined upon radio links formed between mobile stations and the network part of the communication system. Here, two mobile stations 12 are shown – the mobile station 12-1 and the mobile station 12-N.

In the exemplary implementation, the communication system forms an IS-95/IS-2000 cellular radio communication system in which 1xEV-DO technology is deployed. The following

description of exemplary operation of the communication system, and of operation of an embodiment of the present invention employed therein, shall be described with respect to the exemplary implementation. The teachings of the present invention are, of course, also implementable in other types of communication systems by which to facilitate effectuation of control over the power levels of signals communicated therein.

The communication system provides for two-way communications between the network part of the communication system and mobile stations operable therein. Radio links formed between the mobile stations and the network portion define, thereby, both forward link portions and reverse link portions. A radio link 14 extending between the mobile station 12-1 and the network portion of the communication system is here, therefore, shown to include a forward link portion 16 and a reverse link portion 18. An analogous radio link, including corresponding forward and reverse link portions can also be presented.

Data communicated to the mobile station is communicated upon the forward link portion 16, and data communicated by the mobile station to the network portion is communicated upon the reverse link 18. Data communicated by the mobile station to the network portion includes feedback information used pursuant to operation of an embodiment of the present invention by which to effectuate power control of data communicated upon the forward link portion 16 to the mobile station.

The network portion of the communication system includes a radio access network (RAN) 22. The radio access network forms the radio part of the network portion of the communication system. Here, the radio access network is shown to include a base transceiver station (BTS) 24. The base transceiver station is operable, amongst other things, to transceive data communicated upon the radio link 14. The base transceiver station is coupled to a base

station controller (BSC) 26 that also forms a portion of the radio access network. The base station controller is operable, amongst other things, to control operation of the base transceiver station. And, the base station controller is coupled to a mobile switching center (MSC) 28.

The network portion of the communication system here further includes a network backbone, such as a PSTN (public-switched, telephonic network) or a PDN (packet data network), such as the internet. Circuit-switched data or packet-switched data, as appropriate, is routed through the network backbone pursuant to a communication session to effectuate communication of data between, a correspondent node (CN) 34 and a mobile station. The correspondent node is representative of any communication device from which data is originated or to which data is terminated.

The mobile station 12-1 includes a receive portion 36 and a transmit portion 38. Data communicated to the mobile station upon the forward link portion 16 of the radio link is detected, and operated upon, by the receive portion 36. And, data originated at the mobile station for communication upon the reverse link portion 18 of the radio link is operated upon the transmit portion 38. The mobile station 12-N, as well as other mobile stations, includes corresponding structure. And, the corresponding structure of the mobile station 12-N is commonly-referenced.

The mobile station 12-1 further includes apparatus 42 of an embodiment of the present invention. The mobile station 12-N includes corresponding, commonly-referenced apparatus. The apparatus includes elements which are functionally represented in the figure. While in the exemplary implementation, the elements forming the apparatus 42 are implemented as algorithms executable by processing circuitry, the functionality of the elements of the apparatus are implementable in any desired manner.

Here, the apparatus 42 shown to include a first channel condition indicia measurer 44 and a first data rate selector 46. The measurer 44 is coupled to the receive portion 36 of the mobile station. Data communicated to the mobile station upon the forward link portion of the radio link is detected, and operated upon, by the receive portion 36. The measurer 44 monitors communication conditions upon the forward link portion of the radio link. Here, more particularly, in the exemplary implementation, communication conditions on a MAC (Medium Access Control) channel defined in the IS-95/IS-2000 system in which 1xEV-DO technology is deployed are monitored. By monitoring the data communicated to the mobile station upon the MAC channel, the measurer measures, or otherwise determines, the channel conditions, here, e.g., referenced in terms of a channel quality indicia, of the MAC channel.

A value representative of the measured indicia is provided to the first data rate selector. Selection is made at the data rate selector of the data rate at which subsequent data shall be requested to be communicated to the mobile station. When communication conditions upon the MAC channel are good, indicated by the channel condition indicia measured by the measurer, the selector selects a relatively high data rate at which to send subsequent data to the mobile station. If, conversely, measurements made by the measurer indicate the channel conditions to be relatively poor, the selector selects a relatively low data rate at which to communicate subsequent data to the mobile station.

Here, the apparatus 42 further includes a DRC (data rate control) command generator 48 coupled to the selector 46 to receive an indication of selection made by the selector. The command generator generates a DRC command of a value responsive to the value of the selection made by the selector. The values permitted of the DRC command generator are

selected from an allowable set of values. The allowable set is defined, for instance, in the IS-95/IS-2000 operational specification that pertains to 1xEV-DO technology.

The DRC command generator is coupled to the transmit portion 38, and the transmit portion operates to send the DRC command upon the reverse link portion 18 of the radio link back to the network part of the communication system.

The radio access network includes further apparatus 42 of an embodiment of the present invention. Again, the apparatus is functionally represented and includes functional elements that are implemented in any desired manner at a selected device, or combination of devices of the radio access network. Again, in the exemplary implementation, the functions performed by the apparatus 42 are implemented, at least in part, by algorithms executable by processing circuitry. In the figure, the further apparatus positioned at the radio access network is represented to be embodied at the base station controller and base transceiver station, together forming a base station system (BSS) of the network. The further apparatus, in other implementations, is implemented at other structure of the radio access network, or elsewhere in the communication system.

The further apparatus 42 includes a data rate selection value detector 54 and a power level selector 56 coupled thereto.

The data rate selection value detector 54 is coupled to receive an indication of the data rate selection made by the mobile station 12. Analogously, data rate selection is made by other mobile stations, such as the mobile station 12-N, and returned upon reverse link portions of radio links formed with the radio access network are also detected by the detector 54. In the exemplary implementation in which the mobile stations include DRC generators for generating DRC commands, the detector is operable to detect values of the DRC commands.

Detections made by the detector are provided to the power level selector 56. The power level selector selects the power level at which subsequent data communicated upon the MAC channel is communicated to the mobile station 12 responsive to the detection of the requested data rates detected by the detector 54. A metric associates power levels with data rates. In general, when a higher data rate is requested, a lower power level is required to communicate the subsequent data as the higher data rate is associated, generally, with measurements of good channel conditions. Conversely, requests for lower data rates are generally associated with higher required power levels as a request for a low data rate is generally associated with measurement of poor channel conditions.

Additionally, the power level selections made by the power level selector are also made such that the total power levels of all of the data communicated upon the MAC channel to separate ones of the mobile stations are within an allowable maximum value. Thereby, the power level allocations made by the power level selector are further responsive to the maximum allowable power level of all communications permitted on the MAC channel.

Figure 2 illustrates a functional representation, shown at 60, of the manner by which scaling of power levels allocated by the power level selector 56 (shown in Figure 1) is performed to maintain the maximum power levels of all of the data communicated upon the MAC channel within a maximum total power level.

The lines 62 are representative of lines upon which MAC data to be communicated to active mobile stations are generated, such as in the transmit portion of the base transceiver station 24 (shown in Figure 1) of the radio access network. L separate lines are representative of data sent to L separate mobile stations. Each of the lines 62 is coupled to a variable gain element

64. The variable gain element amplifies the data provided thereto upon the respective ones of the lines 62 according to a selected gain.

Here, the gain is indicated by G (DRC). Separate gains levels G are associated with the different lines 62. The power levels are summed together by a summer 66 and the total output power levels are represented on the line 68. Appropriate selection of the separate gains G of the separate gain elements 64 are made such that the total power levels of the line 68 are within a selected maximum power level. As the gain associated with each of the gain elements 64 is related to a gain value, G, and a value of a DRC (Data Rate Command) the gain by which the data generated on the separate line 62 is dependent both upon the data rate requested by an associated mobile station and also the gain G selected by which to amplify the data.

That is to say, the total power, P_t is subdivided amongst all N current users, i.e., mobile stations, that are assigned a Walsh code for communication of data upon the MAC channel. The average power allocated to each user is, therefore, P_t/N. To allocate power levels at which to communicate the separate data to the separate users, B classes of gain are defined. The classes of gain correspond to B levels of DRC available in the communication system. The individual users are allocated power according to:

$$\frac{P_t}{N} G_I(DRC)$$

Wherein:

G_I is the gain related to the Bth set for the Ith user;

N is the number of users which are assigned a Walsh code;

and DRC is the value of the data rate command.

The gains are allocated on a per-user basis for all users where the gain function G is solved under the total power constraint of:

$$P_t = \sum_{l=1}^{L} \frac{P_l}{N} G_l(DRC)$$

wherein L is the total number of MAC users.

Figure 3 illustrates a method flow diagram, shown generally at 82, of an embodiment of the present invention. The method facilitates selection of a power level at which first-selected forward link data is communicated in a two-way radio communication system.

First, and as indicated by the block 84, measurement is made at the first selected mobile station, of an indicia of communication condition levels upon the forward link channel. Then, and as indicated by the block 86, a first channel condition indicia value is formed. The first channel quality indicia value is of a value responsive to the measurements made during the operation of measuring.

Then, and as indicated by the block 88, a first data rate at which to communicate subsequent first-selected, forward-link data upon the forward link is selected. And, as indicated by the block 92, a first data rate selection value is formed.

Then, and as indicated by the block 94, the first data rate selection value is sent to the network station. And, as indicated by the block 96, the first data rate selection value is detected, upon reception at the network station. And, as indicated by the block 98, the power level at which to communicate the first-selected, forward-link data is selected.

Through operation of an embodiment of the present invention, thereby, the power level at which data is communicated upon a shared channel, such as a MAC channel, is selected. Power control of communication of data upon the channel is controlled thereby. The effectuation of the power control is made while utilizing an existing communication metric of data rate feedback requests.

The preferred descriptions are of preferred examples for implementing the invention, and the scope of the invention should not necessarily be limited by this description. The scope of the present invention is defined by the following claims.